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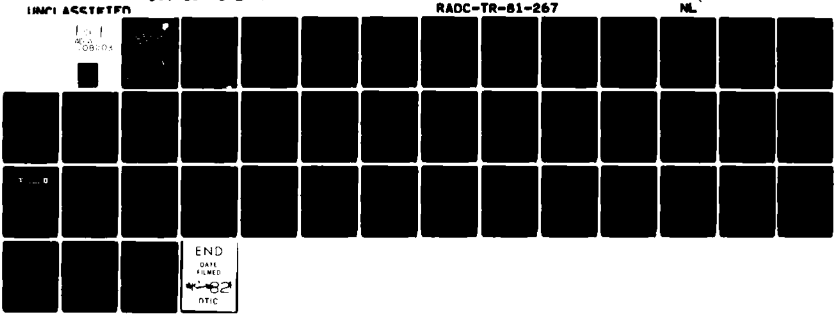

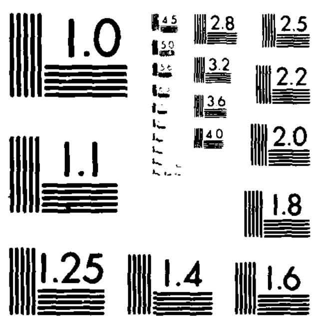

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RADC-TR-81-267
Final Technical Report
October 1981

AD A109203

AN ASSESSMENT OF THE MAGNITUDE OF ELECTROMECHANICAL FAILURES OCCURRING WITHIN AIR FORCE COMMAND, CONTROL, COMMUNICATIONS, AND INTELLIGENCE (C^3I) SYSTEMS

IIT Research Institute

John E. Short

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ROME AIR DEVELOPMENT CENTER
Air Force Systems Command
Griffiss Air Force Base, New York 13441

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RADC-TR-81-267 has been reviewed and is approved for publication.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The failure of mechanical or electromechanical components in systems and equipment does have a direct bearing upon the operational reliability and the logistic support costs. The basic objective of this assessment was to obtain and review all readily available historical and statistical data on selected C^3I systems and components. The second was to obtain through structured but informal discussions the opinions and observations of qualified experts in each phase of system planning, research, develop-

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ment, acquisition, operations and logistic support of C^3I systems.

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1.0 ASSESSMENT OBJECTIVES

The objective of this assessment was to acquire baseline data from which the Air Force (RADC) could establish future efforts for electromechanical and mechanical reliability prediction of C^3I nonelectronic equipment directed toward preventing electromechanical failures. The assessment objectives were to be achieved by: (a) reviewing available government data, (b) quantifying field failure data by hardware type and failure cause, and (c) assessing the adequacy of field reporting systems and providing recommendations which could be used by the government as a basis for improving field failure data feedback.

2.0 REPORT SUMMARY

The failure of mechanical or electromechanical components in Air Force systems and equipment does have a direct bearing upon the operational reliability and the logistic support costs associated with the systems. The basic objective of this assessment was to try to determine the magnitude of the problem.

Two approaches were followed in performing the assessment. The first was to obtain and review all readily available historical and statistical data on selected C^3I systems and components. The second was to obtain through structured but informal discussions of the opinions and observations of qualified experts in each phase of system planning, research development, acquisition, operations and logistic support of C^3I systems.

The major findings of this assessment are:

- The Air Force's Maintenance Data Collection and Analysis System (AFM 66-1), and the <u>standard</u> data products produced from it provide little or no visibility of failures occurring at the component level within Air Force systems, subsystems, or equipment.

- Except for actions taken as a result of unusual circumstances, little or no effort is undertaken within the Air Force to investigate the technical cause of failure or the effect of failure at the component level.

- There are no contractually enforceable design standards or guides within the Air Force that would assist equipment designers in the proper selection and application of mechanical and electromechanical components.

- Advancing technologies are reducing the need for mechanical and electromechanical components within systems; however, their application continues in current systems and will continue into the foreseeable future.

- Although it is difficult to find the impact of mechanical or electromechanical component failures upon systems from the Air Force's maintenance data base, problems do exist with these components as evidenced by the number and cost of replenishment spares being procured on an annual basis. For example, during a twelve-month period the Air Force spent in excess of $5.5 million for replacement motors, synchroes, and resolvers alone.

From these findings and from the overall assessment that was performed it is strongly recommended that:

- The Air Force Systems Command (RADC) establish with the Air Force Logistics Command (AFLC) a requirement for selectively choosing <u>nonstandard</u> data products such as were obtained and used in this assessment to provide technical visibility not readily obtainable from the standard AFM 66-1 data products.

- The Air Force Systems Command develop and contractually apply a military standard to the selection and application of mechanical and electromechanical components within systems, subsystems, and equipment similar to MIL-STD-1515 (fasteners) and MIL-STD-1599 (miniature bearings), and under the management approach used to develop and keep current each of these documents.

- RADC initiate an immediate program to establish a technical base of understanding of the generic modes of failure of mechanical and electromechanical components derived from laboratory failure mode analysis of failed components obtained from field or depot condemnations.

- The results of component failure mode analysis be returned to the appropriate Air Force commodity managers so that corrective component design changes can be required of vendors or, if economically practical, items currently categorized as expendable may be repaired and returned as serviceable.

3.0 ASSESSMENT METHODOLOGY AND FINDINGS DATA BASE

As a departure point for the assessment and to keep the assessment within contractual time and dollar limitations, the Air Force 407-L Tactical Command and Control System was chosen from among many possible candidate systems. The 407-L System was chosen because of the statistically significant number of systems within the operational inventory, the complexity of the system, and its many variants. However, the assessment was not totally limited to the 407-L System. It was, however, the only one deeply pursued for data base information.

It should be noted that throughout the assessment the search through data was keyed to identifying those elements within the 407-L System contributing most significantly to low MTBF's and excessive maintenance

actions and the possible or provable relationship of mechanical or electromechanical component failure to MTBF or maintenance problems. It was assumed that the statistical relevancy of failures at the component level would be reflected in the numbers associated with the next higher level of assembly.

Having chosen the 407-L System as the prime candidate for the assessment, the first indenture in the data search was the obtaining of a Reliability and Maintainability Index (RMI) on the 407-L8K and 407-L8L elements of the 407-L System. (The RMI computer generated data package which is described in Attachment 1 is a unique and essentially nonstandard AFM 66-1 data product developed by and available only through the Logistics Analysis Section of the Directorate of Material Management at the Oklahoma City ALC (OC-ALC/M MEAL).) The composition of the 407-L8K and 407-L8L elements are tabulated under Attachment 2. The RMI clearly indicated that the Work Unit Code Items for the Transceiver C-0 and the Receiver Transmitter RT-742 had the lowest MTBF's, highest number of failures, greatest number of maintenance actions, shortest time between maintenance actions, and consumed the greatest number of maintenance manhours than any other subsystem within the 407-L8K element. The RMI also showed a similar pattern of low reliability and high maintenance for the RF Amplifier in the AN/TRC-97 radio set of the 407-L8L element. (The RMI used in this assessment is retained under File A and is part of this report.)

The RMI, in addition to a summary tabulation of those work unit coded items showing the lowest MTBF's and highest maintenance actions, also has recorded in it the number of failures, the MTBF, the number of maintenance actions, the mean time between maintenance, maintenance manhours, and maintenance manhours/100 operating hours for every work unit coded assembly within the entire system. It is important at this point to understand that a work unit code applies to a specific component or subassembly that can be either removed and replaced, cleaned, or calibrated in the field or returned from the field to a repair center for repair. Mechanical or

electromechanical components (piece parts) are not generally work unit coded for they are generally repair center replacement only items in the next higher order of assembly. However, a review of all work unit coded items within the referenced RMI that were obviously mechanical or electromechanical in nature was undertaken to serve as a guide for possible further investigation. It was found that purely mechanical components such as antenna mountings and electromechanical components such as relay boards and tuning drives generally evidenced exceedingly high MTBF's and low maintenance manhours/100 operating hours. Therefore, no further data or information was sought on these items.

Because the Transceiver C-O and the Receiver Transmitter RT-742 in the AN/MRC-107 ( ) Comm Central were the major drivers of low MTBF and high maintenance actions in the 407-L8K element, a review was made of the data recording all field level parts replaced over a twelve-month period (DO-56B 5LOG) looking for mechanical or electromechanical component failure information. Of a total of 90 piece parts replaced in Transceiver C-O, *only five replaced parts (four relays, one switch)* could be considered as electromechanical or mechanical components. All other component failures were clearly electronic components, i.e., transistors, crystals, tubes, resistors, etc. The same pattern was found true with respect to the RT-742. During the same twelve-month period, 98 piece parts were replaced in the field and only one electromechanical component, a relay, failed. All other failures were electronic components. (The DO-56B 5LOG providing the preceding data is retained under File B and is a part of this report.)

In support of this investigation, Hq AFLC provided a Standard Reliability and Maintainability Report on the TPS-43X and TPS-43E Radar of the 407-L System. Time did not permit a manual tabulation of all reported field failures and repairs. However, a random sampling of 25 work unit coded subassemblies revealed that of 183 component failures only 10 were

mechanical or electromechanical components. (The Standard Reliability and Maintainability Reports on the TPS-43X and TPS-43E radars are retained under File C and are a part of this report.)

The overall assessment of these probes into both the standard and nonstandard data products derivable from the AFM 66-1 data base is that there is little recorded evidence that mechanical or electromechanical components are adversely affecting the reliability, maintainability, or logistic support costs associated with ground based C^3I systems. However, it must be remembered that many of these components are not work unit coded as field maintenance items and therefore would not show within the data base.

Although this assessment was primarily focused on ground based C^3I systems, a Reliability and Maintainability Index was obtained on the E-3A (AWACS), AWACS being representative of a later generation of C^3I systems. A similar index was obtained on the F-16 in hopes of determining whether or not the more extreme environmental conditions seen by airborne equipment and components had any determinable impact on mechanical and electromechanical devices in comparison to the effects of environment as seen by ground based systems. In reviewing the AWACS data specifically related to mission subsystems and equipment, no specific trends were noted that would indicate that later generation C^3I systems even with fewer mechanical and electromechanical components represent significant improvement in either system reliability or fewer maintenance actions. System complexity rather than component reliability continues to be the factor of greatest influence. Aeronautical systems, as would be expected, contain far more mechanical and electromechanical components than ground based systems and the work unit coding of the F-16 dramatically demonstrates the comparison. In reviewing the F-16 data, devices such as seals, hinges, latches, servoactuators, transducers, and solenoids all, almost without exception, had exceedingly high MTBFs and were low maintenance items, thus proving that, even though the F-16 sees extreme environments, if environmental

conditions are considered in the selection and application of mechanical and electromechanical components, high reliabilities can be achieved. (The E-3A and F-16 Reliability and Maintainability Indexes are retained under File D and are a part of this report.)

Although it is possible, it is extremely difficult to obtain from AFLC's Technology Repair Centers depot level piece part replacement information on assemblies and subassemblies returned from the field to the depot for repair. Therefore, another approach to dimensioning the problem under assessment was followed. Sacramento ALC procures many of the Air Force piece parts and components that are used during the repair process of both ground and airborne electronic systems.* A review was made of just two Federal Supply Classes (FSC) managed by the Sacramento ALC. They were FSC 5990 synchroes and resolvers and FSC 6105 electrical motors. Although synchros, resolvers and electrical motors do not appear from the AFM 66-1 data base as operational or logistical problems, the fact remains that the Air Force is expending in excess of $5 million annually to provide replacements or replacement parts to Air Force electronic repair centers for these minor components alone. (This data was obtained from Air Force DO-62 Data Files and is retained under File D and is a part of this report.)

3.1 Component Failure Impact Assessments. The fact that mechanical and electromechanical components in both ground and airborne electronic systems are failing as evidenced by the annual cost of replenishment spares, very seldom is an analysis made of the total effect of discrete component failures on total system performance. Component failures are generally treated by AFLC on a problem-by-problem basis.

*If a component is also used by another Service it is generally procured by the DoD Electronic Supply Center.

There are, however, several case histories in the files of the Air Force's Rivet Gyro/PRAM Program Office indicating the value of component failure impact analysis when it is performed. In the final report of the Rivet Gyro Phase I investigation into the low reliability of the F-4 ASN-63 Inertial Navigation System, it was reported that "Reports from both RADC and ASD indicated that electronic components were failing due to electrical overstress caused by high voltage transients on power surges. Efforts were initiated to identify JAN TX parts that could be used in place of the most failure prone components. The items singled out for special effort for immediate improvement were: (a) velocity potentiometers, (b) solenoids, (c) blowers, (d) relays, (e) capacitance tachometer switches, and (f) welded wire modules. With the recommended changes incorporated, it is computed that MTBF of the CP-733 computer can be raised from 79 hours to 146 hours."

The Rivet Gyro investigation into the F-111 AJQ-20 Inertial Navigation System concluded that "Within the stable platform unit (SPU) the accelerated integrator module has one of the highest module maintenance return rates. SMAMA data for the period of 1972 indicated that this module accounted for 31.8% of SPU failures and 7.4% of the SPU module maintenance costs. Within the module the servomotor, friction bearings, spur gear, capacitance tachometer rotary switch, velocity potentiometer, and servo-amplifier were found to be the piece parts with the highest failure/replacement rates. The latitude and longitude modules within the Navigation Computer (NCU) have one of the highest depot return rates within the NCU. During the period of 1972 SMAMA data indicated that these two modules accounted for 40.7% of the NCU module failures and 48.1% of the NCU module maintenance costs. The high removal piece parts within these two modules are the friction washer, microswitch, captach, vernistat, and control motor."

3.2 Component Failure Mode Analysis. Very seldom is an engineering failure mode analysis made of failed components. Therefore, there is currently no data base to draw upon that could guide equipment designers in the proper selection and application of mechanical or electromechanical components; failed components only receive engineering attention when the component becomes a "hi burner." At the present time, the Sacramento ALC/MMCR does not see mechanical or electromechanical components as a major problem in ground based electronic systems as stated in a message from the ALC to Hq AFLC which is quoted in part in the following:

> "We have made a survey of the ground C-E inventory for electromechanical or mechanical high burner repair items. There are relatively few components which might be classified in the hi burner failure/repair category; however, those possible candidates have a low population density. Further, we are replacing those types of components with solid state devices wherever possible."

> "When a hi burner repair item surfaces, we investigate the failure through Halifax (Contract Engineers), and develop a fix or replacement. Also, the low population and scant numbers of hi burner items barely generate enough activity to fulfill the PRAM and value engineering goals."

3.3 Trends. Mechanical and electromechanical components do fail in Air Force systems as evidenced by the annual procurement of replenishment spares even though the maintenance data system does not record the impact of these failures on systems, and knowing that advancing technologies such as solid state switching is replacing electromechanical switching, an attempt was made to assess the impact of these advances on the formulation of Air Force (RADC) reliability research programs. Two data points were obtained, both indicating that mechanical and electromechanical components are rapidly becoming fewer in number as todays state-of-the-art is being applied in the design of newer systems. For example, Westinghouse who has

been the designer and producer of the TPS-43 series of radars indicated that there are approximately 60% fewer mechanical or electromechanical components in the most current version of the radar as compared to the original design. The Sacramento ALC in its comparison between the AN/UPA-35 and the AN/UPA-62 Indicator Groups points out a significant reduction of electromechanical components in the newer configuration. (See Attachment 3. Attachments referred to in Attachment 3 are retained under File F and are a part of this report.)

3.4 Structured Interviews and Discussions. During the period of this assessment, interviews and discussions were held with qualified individuals experienced in each phase of the development, acquisition, deployment and logistic support phases of C^3I Systems. The pertinent points resulting from each discussion relative to this assessment were recorded as follows:

3.4.1 Electronic Systems Division - AFSC. There is a major trend to procure commercially available equipment for ground based C^3I systems whenever practical. However, when commercial equipment is not suitable or available to satisfy Air Force needs, then a development/acquisition program is initiated. At the present time there are no contractually enforceable specifications or standards that would govern a contractors selection or application of mechanical or electromechanical components.

3.4.2 Tactical Air Warfare Center - TAC. The 727th Tactical Control Squadron (Technical) maintains all of the ground electronic Command and Control equipment used in support of and Blue Flag exercises and the Air Ground Operations School. In discussions with their senior maintenance personnel they indicated that, while mechanical and electromechanical components within equipment were a negligible problem, excessive damage and additional maintenance workload was being caused by the severe environment (shock and vibration) seen by sensitive equipment during field

maintenance transportation frequently generated as a result of "too frequent calibration requirements."

3.4.3 E-3A AWACS Maintenance - TAC. The Director Maintenance (DM) (AWACS) indicated that to his knowledge mechanical and electromechanical components within the AWACS specialized systems were not of themselves major problems. His major problem is one generated by the unique logistic support requirements and constraints associated with AWACS. He also indicated that significantly higher System MTBF's are being experienced on operational missions as compared to training missions. He relates the increase as being due to fewer on-off cycles as a function of time.

3.4.4 E-3A AWACS Systems Management - AFLC. A discussion with the AFLC E-3A Systems Manager (SM) supported the TAC DM's statement that mechanical and electromechanical components are not visible problems within the AWACS specialized systems.

3.4.5 Sacramento Air Logistics Center - AFLC. Extensive discussions with personnel from within the Directorates of Material Management (MM) and Maintenance of the ALC disclosed that piece parts wear out and obsolescence is their major problem in performing depot support of ground based electronic systems. They pointed out that some of the systems that they must continue to support have been in the inventory over thirty years and that mechanical and electromechanical components that must be replaced can no longer be procured.* The ALC people feel that shelter corrosion is the major environmental cause of degradation of mechanical and electromechanical components. However, the "power quality" of ground power generators, power distribution systems and the poor design of equipment cooling systems (ECUs) contribute far more than all other problems to

*Note, of the 6,922 aircraft in the Air Force's operational inventory, only 5% are older than 20 years, 67% have been the inventory less than 15 years.

failure of ground electronic systems and their components. It was also their opinion that small systems such as the FPS-77 procured in small quantities do not receive adequate engineering attention to the selection and application of electromechanical components. They cited the antenna drive motor of the FPS-77 as being of poor design, requiring 100% replacement at cost of approximately $500/unit. It was their observation that although many mechanically driven devices such as antennas are being replaced by phased arrays, mechanical problems such as are being experienced on Cobra Dane and Pave Paws liquid cooling systems relative to valves, seals, and expansion joints will continue to exist as long as these devices are built to "commercial standards."

4.0 ASSESSMENT CONCLUSIONS

From the preceding, it is concluded that:

(1) Standard AFM 66-1 data products provide little insight into the impact of mechanical and electromechanical component failures in ground (and airborne) C^3I Systems (see Note 1 following Recommendations).

(2) The nonstandard data products derived from the AFM 66-1 data base, such as the OCAMA R&M Indexes are extremely helpful in identifying critical areas for further investigation; however, they in themselves contain little information of engineering nature.

(3) Component failure impact assessments are rarely performed on systems, and component failure mode analyses are performed even less frequently; thus there is currently no valid data base that relates mechanical or electromechanical component failures by either hardware type or failure cause.

(4) When component failure modes are investigated and corrective action is taken, significant improvements to component reliability can frequently be achieved along with an attendant reduction in support costs. For example, PRAM's investigation of the AN/ALT-28 Antenna Wave Guide Switch resulted in a reduction of the failure rate of installed switches from 190 during the first year to 10 in a six-month period. A five-year logistic cost savings of $223,000 has been computed (see Attachment 4).

(5) The cost of mechanical and electromechanical component failures in systems cannot be readily identified; however, it is at a minimum equal to the cost of replenishment spares. Knowing that in excess of $5.5 million are expended annually for Air Force peculiar replacement synchros, resolvers, and motors, it is then conservatively estimated that the total cost for all mechanical and electromechanical components, which would include such items as circuit breakers, switches, connectors, relays, and solenoids, would probably approach an annual cost of $8 - 10 million.

(6) Although mechanical and electromechanical components are being reduced in the newer systems, they will continue to appear to some degree in all systems in the foreseeable future.

(7) In the absence of Air Force design guides applicable to the selection and application of mechanical and electromechanical components, industry will continue to use "good engineering practices" and "commercial standards," which can and frequently have impacted operational capabilities and logistic support costs.

5.0 ASSESSMENT RECOMMENDATIONS

It is strongly recommended that AFSC/RADC:

(1) Establish a formal and continuing requirement with Hq AFLC/Oklahoma ALC for the expansion of Reliability and Maintainability Indexes into ground based C^3I Systems.

(2) Initiate the development of a mechanical and electromechanical component failure mode data base by:

(a) Recovering from the various ALC's and field maintenance organizations all components of interest that have failed and been removed, and

(b) Either organically or with the assistance of a technically qualified independent and industry acceptable support contractor perform and record a failure mode analysis of each of the failed components.

(c) Feed back to the ALC's the findings of component failure mode analysis so that component design changes can be initiated and, where practical, an economic assessment of the repairability of condemned items.

(d) Initiate the development of a MIL-STD document similar to MIL-STD-1515 (fastener systems) and MIL-STD-1599 (miniature bearings) that can be used as a contractual requirement in the selection and application of mechanical and electromechanical components in Air Force Systems. (A model for managing the development of the recommended MIL-STD is retained under File G and is a part of this report.)

(e) Expand the limited investigation that was made into component replacement costs to include other clearly identifiable areas.

NOTE 1: AFM 66-1 Standard Data Products

The Standard AFM 66-1 Data Products, to which frequent reference has been made in this report, have as their origin AFTO 349 Forms which are prepared by field and depot maintenance personnel for each maintenance action performed on a Work Unit Coded item within a system, subsystem or equipment. The 349 data base combined with other data sources, such as aircraft utilization information, comprise the Air Force's D056 Product Performance System which stores, tabulates and distributes maintenance data to a variety of users by means of five standard data products. They are:

D056A - Outputs to other AFLC data systems
D056B - Reports "ON" equipment maintenance
D056C - Reports "OFF" equipment maintenance
D056E - Provides selected data tapes to contractors
D056T - Reliability and maintainability analysis

Although the D056B, C and T data products provide extensive information on the nature of the maintenance action performed, maintenance manhours expended and meantime between maintenance, very little information of engineering significance is captured by the AFTO 349 forms and therefore the D056 standard data products can only at best provide clues as to where major technical problems may exist. To modify the Air Force's current maintenance data collection and analysis system to acquire data essential to the identification and resolution of technical problems would be a monumental undertaking. It has been generally found that the acquisition of technical information and engineering data requires a special effort within the Air Force.

The non-standard data products referenced in this report differ primarily from the standard D056 data products in the formatting of the information provided for ease of interpretation, and the rapid correlation of information that is usually distributed between two or more D056 standard data products.

Descriptive information pertaining to the Air Force's Product Performance Information System and the D056 data products is retained under File H and is part of this report.

APPENDIX A

ATTACHMENTS

A-1

Reliability and Maintainability Index (RMI)

INTRODUCTION

The RMI has been developed to provide the System Manager (SM) and Item Manager (IM) with a data product permitting rapid visibility in the assessment of reliability and maintainability of a given weapon system.

DATA SOURCE

Inputs for the RMI are extracted from DO-56B summary master data tapes. These tapes are generated from field maintenance reporting through the Air Force Maintenance Data Collection (MDC) System. Data summary tapes and B-4 master record tapes are required for RMI input.

METHODOLOGY

Required data tapes are accessed through the OC-ALC CREATE computer system. Locally developed computer programs are utilized to process the desired data and provide output products.

DATA PRODUCTS

1. Data products are produced only on hard copy at this time.
2. An RMI run is normally produced on a complete weapon system. The following data is provided on each work unit coded item within the weapon:

    a) Work Unit Code (WUC)
    b) Nomenclature
    c) Failures
    d) Mean-Time-Between-Failure (MTBF)

e) Total Maintenance Actions

f) Mean-Time-Between-Maintenance (MTBM)

g) Maintenance Manhours Expended (manhours for inspections not included, Support General WUCs)

h) Maintenance manhours per 100 operating hours

3. In addition, subtotals of the above data are provided at each subsystem and system indenture. The last page of output gives totals for the entire weapon.

4. RMI products normally utilize 12 months of data.

407-L8K and 407-L8L Elements of the 407-L System

407-L8K

AN/PRC-47	Portable radio
AN/PRC-66B	Portable radio
MX 857GT	Pallet set
AN/GRC-175	Ground radio set
AN/MRC-107( )	Comm Central
AN/MRC-108( )	Comm Central
TGC-26( )	Comm Central
TGC-27( )	Comm Central teletype
TGC-28( )	Comm Central teletype
S-530 A/G	Shelter
AN/TPS-43X	Radar set
AN/TPS-43E	Radar set (3 variants)

407-L8L

---	Cable reel pallet
AN/TRC-87	Radio set
AN/TRC-97A	Radio set
AN/TSC-53	Comm set
AN/TSC-60(V)1	Comm Central
AN/TSC-60(V)2	Comm Central
AN/TSC-60(V)3	Comm Central
AN/TSC-62	Comm Central
AN/TSM-109	Test set
AN/TSQ-61	Operation Central
AN/TSC-15	Teletypewriter set
AN/TSW-7	Air Traffic Control Center
AN/VRC-46	Radio set
AN/TRN-26	Tacan
AN/GSQ-120(V)	
AN/TSQ-91( )	CRC/CRP
AN/TSQ-92(V)2	TACC
AN/TSQ-93(V)3	DASC
AN/TTC-32	Switchboard

Sacramento ALC Analysis of Electromechanical Device Trends

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS SACRAMENTO AIR LOGISTICS CENTER (AFLC)
McCLELLAN AIR FORCE BASE, CALIFORNIA 95652

18 APR 1981

REPLY TO ATTN OF: MAI

SUBJECT: Electromechanical Devices Trend in Air Force Equipment

TO: Mr. John E. Short
221 Stanford Pl.
Springfield, OH 45503

1. The enclosed documents are provided as a result of your visit here last month. As we discussed, our older equipment have a higher percentage of electromechanical devices than newer equipment which have more electronics. That trend is indicated, in a small way, by the comparison of these two units.

2. We have provided you with a copy of:

a. The AN/UPA-35 Technical Order.

b. The Full Range List of our AN/UPA-35. This list shows the items that go into the make up of the AN/UPA-35.

c. Our Bill of Material (BOM) (developed for depot repair) with electromechanical items underlined in red.

3. The AN/UPA-35 is an indicator group which provides visual display of azimuth, range and height (absolute and relative) associated with search and height finding sets. Approximate age 25-30 years.

4. The AN/UPA-62 is a newer indicator group. It is a general purpose plan position indicator that can be used with radar sets for surveillance, ground control intercept, identification and air traffic control. It is a self contained unit. It requires input from timing triggers, video, and antenna position data from the associated radar set. Approximate age 5-10 years. For this indicator group we have provided a copy of the Full Range List, our inventory check list and the technical order. (Reference page 2-67 for electromechanical item.) We do not have a BOM for this indicator group. It has not been programmed to date for repair as an indicator group.

5. Our review indicates that the AN/UPA-35 has seven (7) electromechanical items identified, whereas, the AN/UPA-62 has only one.

AFLC - Lifeline of the Aerospace Team

6. The technical orders should be all that you need for your purpose. However, I have included the other attachments for your reference. If I can be of further assistance, please call me at 916 643-3906.

KENNETH G. McCLURE
Chief, Communications-Electronics
Division
Directorate of Maintenance

6 Atch
1. UPA-35 Technical Order
2. Full Range List (UPA-35)
3. Bill of Material
4. Full Range List (UPA-62)
5. Inventory Checklist
6. UPA-62 Technical Order

A-4

PRAM AN/ALT-28 Antenna Wave Guide Switch Investigation

USAF
PRAM PROGRAM
FINAL REPORT

AN/ALT-28 ANTENNA WAVEGUIDE SWITCH INPROVEMENT

Distribution Limitation: Distribution limited to United States agencies only; Test and Evaluation; 20 Sep 1977. Other requests for this document must be referred to ASD/RA, Wright-Patterson AFB, OH, 45433.

Approved by:

Bill Moss, Jr.
BILL MOSS, JR., Colonel, USAF
Director
PRAM Program Office

20 SEP 1977

Project No: 03376-03
Project Officers: Capt M. Todd
Mr. J. White
Telephone No: AV 785-2132

INDEX

INTRODUCTION

The AN/ALT-28 jamming system is a barrage jammer on B-52G and H aircraft designed to cover a wide range of frequencies. During a 1969-1970 B-52 requirement study, a Class V modification to the fleet was proposed to correct certain electronic countermeasure (ECM) shortcomings. As part of the Phase VI ECM improvement modification, two AN/ALT-28 transmitter systems with selectable forward directional antennas and a new panel were added to the system. Electromagnetic energy is transferred from the omni antenna to the forward directional antenna located in the nose radome by means of two identical waveguide switches.

Operationally, the waveguide switch is spring loaded to the omni antenna position. When the forward antenna is selected, 28VDC power is applied through the switch to a solenoid which allows energy to be transferred to the forward antenna. Through a mechanical linkage, a series of microswitches, and other associated electronics, the switch is held in the forward antenna position. A hold-in resistor prevents the solenoid from overheating in this position.

The objective of this project was to identify and correct the causes of the high failure rate and high operational and support costs of the AN/ALT-28 waveguide switch. This objective has been accomplished through the efforts and cooperation of many personnel from Warner Robins ALC/MMI, HQ SAC/LGME, the 2nd and 5th Bomb Wings.

EXECUTIVE SUMMARY

The waveguide switch is an electromechanical device in certain B-52 AN/ALT-28 Electronic Warfare Systems which can be activated by the electronic countermeasures operator to transfer electromagnetic energy between two selectable antennas. The B-52G and H aircraft systems have two waveguide switches each. Approximately one third of all installed switches failed during their first year of operational service.

PRAM, SAC, and WR-ALC initiated a collective investigative effort to determine the cause(s) of switch failures. Several failure modes were discovered which can cause eventual switch linkage or solenoid failure. Premature failure was attributed to a deficiency in the solenoid actuating mechanism design. Initially two recommendations relating to relaxed linkage tolerances and use of an improved lubricant were implemented to temporarily reduce the failure rate while another effort was undertaken to correct the design deficiency. PRAM, in conjunction with MPC Products, Co. developed a modification kit which incorporates an indexing stepper motor to replace the drive solenoid and associated electronics. SAC/LGME conducted operational service tests of six modified switches and the results of these tests indicated that the failure modes have been eliminated.

Implementation of the initial recommendations has reduced the switch failure rate to an acceptable level on a temporary basis (ten failures in the last six months as compared to 95 in the previous six months). The improved stepper motor modification kit, which costs $100 more than the current design but was tested to an equivalent of 35 years duty, will be incorporated on an attrition basis as switches are cycled through the depot repair facility for overhaul.

Cost of the project was $22,527 with attendant net savings of $223,000 in five years.

TECHNICAL INVESTIGATION

This section reports the specific problems, the approaches, findings, and recommendations on two technical tasks:

Task I - Failure Mode Analysis

Task II - Design Improvement Effort

TASK I - FAILURE MODE ANALYSIS

STATEMENT OF THE PROBLEM

Waveguide switches, installed as part of the B-52G and H Phase VI ECM Improvement Modification in 1975, were failing at a rate of 30% annually, creating unacceptable operational and support problems. Cause of failure had to be corrected to increase reliability and operational availability and to reduce support costs.

TECHNICAL APPROACH

In December 1975, a conference was held to discuss and evaluate the problems associated with waveguide switches. Specifications were reviewed, switch cycling tests were conducted, and then a switch was disassembled and examined to determine the modes of failure. In addition, OC-ALC/MMAOM provided several failed switches to ASD/RAO (formerly ASD/RME) for further failure analysis. Evaluation of the failed switches served to further characterize the

failure modes and design deficiencies as determined during the December 1975 waveguide switch meeting. The findings are described in detail below:

FINDINGS

The waveguide switch was failing primarily due to overheating of the solenoid in the drive mechanism. The problem was caused by an inherent design deficiency of the driver mechanism of the switch. The following were noted:

a. Mechanical stops and/or microswitches will not maintain settings due to excessive force from solenoid and/or due to movement associated with metal stress, i.e., temperature related stress, machining related stress, etc.

b. Silicones are specified for use as a lubricant during component assembly. Microswitches will not function properly in a thermal/silicone environment.

c. Tolerance buildup in the solenoid to rotor linkage can cause binding, either from excessive allowable manufacturing tolerance during initial component fabrication or from movement permitted within the completed assembly.

RECOMMENDATIONS

1. Change switch lubricant from silicone base to MIL-G-83261.

2. Increase linkage clearances to decrease mechanical binding.

3. Improve cleaning procedures following switch brazing.

4. Broaden the scope of the investigation to address and correct the design deficiencies identified during this task.

SITUATION/STATUS

Recommendations 1, 2, and 3 were implemented by WR-ALC and have significantly reduced the failure rate of installed switches from 190 during the first year to ten in the last six months. It should be pointed out that this reduction in the failure rate is considered to be only temporary because the basic switch design deficiency has not been corrected.

RECOMMENDED AUDIT METHOD

The audit is complete as indicated in Situation/Status above.

TASK II - DESIGN IMPROVEMENT EFFORT

STATEMENT OF THE PROBLEM

Waveguide switch design deficiencies, as identified in Task I, must be corrected to permanently reduce the failure rate and logistics support cost.

TECHNICAL APPROACH

A contract was negotiated with MPC Products Corporation of Chicago to design and deliver a test quantity of modified waveguide switches. These switches had a 90° indexing stepper motor in place of the solenoid. Six of these switches were service tested at Barksdale and Minot AFBs for six months. Each test aircraft was equipped with one modified switch and one unmodified switch. Following the service test, a limited life cycle test was performed on both the modified and unmodified switch. See attached HQ SAC Engineering Report No. P-268, dated 30 June 1977 for results of this test.

FINDINGS

Two modified switches failed, one in flight and one during lab test, due to failure of the return spring. Spring failure was attributed to fatigue. To meet the prototype delivery and test schedules, the contractor used a non-production spring (wrong K factor and width) which had to be ground down to size. In the grinding process, the

nonproduction springs were burned inducing a weakened area which caused the spring to fail due to fatigue.

The modified switches remained within the switching time specification.

Life cycle tests on the modified switch were terminated after 13,000 cycles, which equates to 35 years duty in the B-52G/H, with one failure.

RECOMMENDATIONS

1. PRAM and the contractor rectify the spring deficiency through use of qualified production springs in the modification kit. Spring adequacy should be verified by test.

2. MPC Products Corporation deliver through PRAM to WR-ALC, an engineering data package describing the modification hardware and installation instruction for procurement purposes.

3. Upper switch assembly be repaired with MPC modification kit on an attrition basis as switches fail and are returned to the repair facility.

4. WR-ALC evaluate the feasibility of incorporating MPC modification into future procurements as the preferred spare.

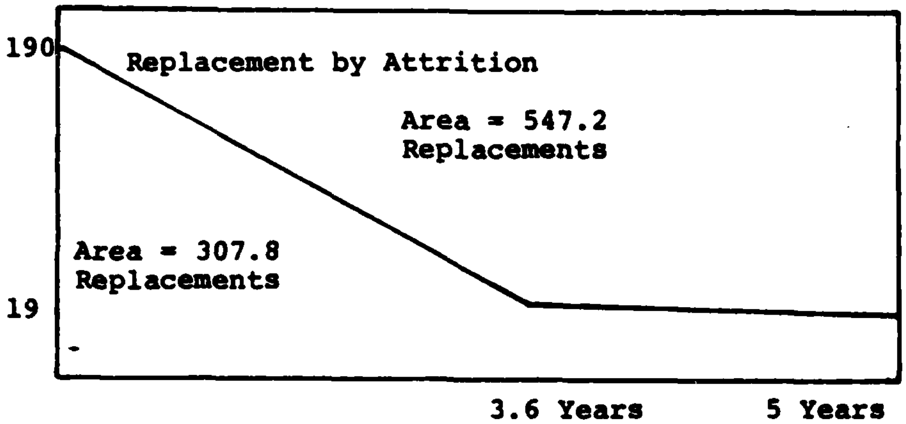
SITUATION/STATUS

The switch failure rate can be held between approximately 19 and 29 failures annually through implementation of the stepper motor modification kit.

RECOMMENDED AUDIT METHOD

The AN/ALT-28 item manager can audit the effect of the switch improvement through AFM 66-1 and D041 appropriate data for a one year period before fix implementation and one year after implementation. Data should be adjusted by the item manager to eliminate variations not pertinent to switch modifications.

ECONOMIC SUMMARY



Current Overhaul Price - $500

MPC Modification Kit Price - $570

190 = Failures during first year of operation

19 = Predicted annual failures after modification

3.6 Yrs = Time to complete modification through attrition

190 X 5 Yrs = 950 Replacements before modification
-547.2 Replacements deleted through modification
402.8 Replacements over 5 yrs after modification

Five Years O&S Costs:

Unmodified Switch: 950 X $500 = $475K

Modified Switch: 402.8 X $570 = 230K

Gross Savings = $245K

PRAM Investment = 22K

Net Savings = $223K

APPROVAL/COORDINATION

Copies of final report sent to HQ SAC/LGME and WR-ALC/MMI 3 October 1977. After coordination, insert proper page and send to printing.

COORDINATION/APPROVAL

OFFICE SYMBOL	NAME/DATE
HQ SAC/LGME	James H. Harrington 4 Nov 77
WR-ALC/MMR	Roy L. Oldham 19 Dec 77
ASD/RAO	Clyde T. Bolen, Jr. 15 Sep 77

APPENDIX B

INDEX TO SUPPORTING FILES

FILE A 407-L8K and 407-L8L Reliability and Maintainability Index

FILE B Transceiver C-0 and RT-742 DO-56B 5LOG

FILE C TPS-43X and TPS-43E Standard Reliability and Maintainability Report

FILE D E-3A and F-16 Reliability and Maintainability Indexes

FILE E Sacramento ALC Annual Procurement Cost for Synchroes, Resolvers, and Electrical Motors

FILE F AN/UPA-35 and AN/UPA-62 Data

FILE G AMFRG Manual

FILE H Air Force Product Performance System

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of
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